Sandia and Applied Materials partnership advances microchip etching capabilities

Partnership ensures that DOE Defense Programs keep pace with leading-edge technologies

In a five-year partnership with Applied Materials, Sandia National Laboratories has helped develop and improve two generations of polysilicon etch chambers used to create integrated circuit patterns on microchips. Sandia extended the performance of the first etching tool from its original 0.5µm/200mm performance to a 0.35µm/200mm capability. Current projects in Applied Materials' latest generation etching equipment are developing the capacity to etch 0.25-µm designs. In return for offering industry its unique resource, the Microelectronics Development Laboratory and in-depth engineering support, Sandia gains the opportunity to participate in the development of next-generation fabrication equipment, ensuring leading-edge microelectronics for DOE's Defense Programs.

The Decoupled Plasma Source chamber for which Sandia engineers developed a robust 0.25µm/200mm etching process is shown installed on Applied Materials' most advanced etching platform. Industry partners have defrayed more than half of the $32.5 million costs of developing the 0.35µm/200mm capability through the donation of equipment, technical interaction, and shared data.

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In microelectronics, when you're keeping up with the Jones's, it's smaller, not bigger, that's better. Sandia National Laboratories and Applied Materials, Inc., have achieved a 0.25-µm etching capability for industrial production of integrated circuits on microchips, and together are pushing toward even smaller pattern designs. The projects are part of a joint partnership in which Sandia offers industry its unique resource, the Microelectronics Development Laboratory (MDL), and industry provides leading edge, next-generation equipment.

Sandia—once at risk of losing its leadership in radiation-hardening technology—is now an active partner with industry in developing next-generation equipment for manufacturing microchips (see sidebar).

It's a match that works well for both DOE's Defense Programs and industry. In a field that creates obsolescence nearly as fast as its products, the only way to maintain preeminence in microelectronics is to continuously confront leading-edge technology issues. Through lab/industry partnerships, Sandia—once at risk of losing its leadership in radiation-hardening technology (see sidebar)—is now an active partner in the development of next-generation equipment for manufacturing microchips. Access to such technology is critical to Sandia's fabrication of custom and radiation-hardened integrated circuits for DOE's Defense Programs and reduces U.S. dependence on foreign manufacturers and equipment suppliers.

With the partnership, Sandia engineers have advanced the capabilities of Applied Materials' next-generation plasma etching equipment, which is used for creating integrated circuit patterns on microchips. Plasma etching is considered a dry etching process and is the process of choice when precision is paramount.

At present, plasma etching equipment is one of the most technically complex of the integrated circuit fabrication set and also the least understood from a fundamental point of view.

The process depends on plasmas, which are collections of charged particles that exhibit some properties of gas and are good conductors of electricity, and chemically active gas mixtures.

Plasma Etching Process

Plasma etching is performed during microchip production. A simplified explanation of the process is that, first, a pattern of circuits is defined by means of a photolithographic technique in which the integrated circuit pattern is drawn on a thin film of photo-sensitive material. Then, during the plasma etching process, low-pressure, high-density plasmas are created in chemically complex mixtures of reactive gases.

Regaining and Maintaining the Cutting Edge

During the early 1980s, Sandia designed, fabricated, and delivered hundreds of thousands of radiation-hardened integrated circuits for use in weapons and satellites.

Until the mid-1980s, Sandia was the premier laboratory for technology innovations and state-of-the-art integrated circuits. But with the emergence of numerous commercial suppliers in the mid-1980s a decision to reduce production efforts at Sandia put a temporary halt to Sandia's preeminent role. By the end of the decade, Sandia's microelectronics infrastructure was obsolete and without an integrated circuit production capability.

Meanwhile, the relatively robust commercial supplier base declined as demand was reduced by the ending of the cold war and the high ongoing cost of recapitalization. When the national need for production capabilities became apparent in the early 1990s, Sandia was able to respond only because of a serendipitous donation by IBM of a complete 0.5 µm/150mm equipment set and semiconductor process technology.

Sandia has since used this equipment to develop and produce radiation-hardened integrated circuits for DOE's Defense Programs. But without continued recapitalization to maintain relevance with commercial manufacturers and their supplier base, Sandia's capabilities would again become outmoded in only one to two technology generations.

Fortunately, technology partnerships, like this one with Applied Materials, have enabled the MDL to keep pace with commercial suppliers by leveraging its present equipment to attract partnerships in next-generation equipment development.

The chemical complexity of the gases is necessary to achieve a high-resolution transfer of the lithographic patterns into one of the thin layers of material that make up a microchip. Power supplies of multiple radio frequencies modulate both the current and energy distribution of the charged species, which etch the pattern into the layer.

A critical step in the production of integrated circuits is the definition of the gate electrode, which is a circuit element that controls the flow of binary information through a transistor and is triggered into operation by an enabling signal. The gate electrode is etched into a conducting film, usually polysilicon or tungsten silicide. With plasma etching, the plasmas created in the chemically complex mixtures of reactive gases control the etching rate of the polysilicon gate electrode relative to the very thin underlying gate oxide layer.

The complex plasma chemistry also controls the precision of the etching by managing the tendency to simultaneously etch polysilicon while depositing a protective film of polymer on the sidewalls of the etched features.

The precision achieved in this etching step directly determines the performance of the integrated circuit. The steady advances in integrated circuit speed and complexity enjoyed since the advent of integrated circuit technology are a direct result of advances in photolithography and etching.

Smaller and Smaller

Sandia's and Applied Materials' engineers first extended Applied Materials' 0.5-µm etching capability in the AMAT P5000 reactor to 0.35-µm features in polysilicon. This improvement offered Applied Materials' customers the advantage of incorporating the new 0.35-µm technology into their base of already installed AMAT P5000 tools.

More recently, Sandia engineers developed a robust process for even smaller designs, a 0.25µm/200mm etching process, using the latest plasma etching technology, a Decoupled Plasma Source (DPS) chamber, installed on their most advanced etching platform. Sandia enjoys first access to this state-of-the-art processing technology to support its MDL programs in radiation-hardened microelectronics and microsystems.

In a follow-on partnership agreement, currently under negotiation, Sandia has been asked to study plasma etching to generate a fundamental understanding of the process. Specifically, Sandia would

MICROELECTRONICS DEVELOPMENT LABORATORY—A UNIQUE RESOURCE

Sandia's Microelectronics Development Laboratory (MDL) is a production-quality clean room facility. Its infrastructure of diagnostic and metrology equipment and in-depth engineering support make the facility a unique resource, ordinarily beyond the financial resources of even the largest equipment manufacturer.

To industry partners such as Applied Materials, it offers not only an exceptional physical facility but also outstanding technical support. For example, as immature equipment is exercised at Sandia using specially designed microelectronic test structures, problems are identified that could not have been anticipated by the partner during its in-house development effort. Sandia engineers at the MDL then draw on Sandia-wide expertise to understand and solve problems that limit the performance of the reactor.

In return, the MDL receives tremendous benefits. Sandia is able to keep pace with commercial suppliers by leveraging its present technology generation, including engineering skills and equipment, to attract partners to co-develop the next generation of technology.

The partner's contribution is next-generation equipment, such as Applied Materials' AMAT 5200 Mainframe. This "boot-strap" approach to recapitalization substantially reduces the MDL's costs and is self-sustaining.

According to estimates by the Center for Manufacturing Technologies at Sandia, the donation of equipment, technical interaction, and shared data by industry partners have defrayed more than half of the $32.5 million costs of developing the 0.35µm/200mm capability.

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investigate the role that neutral and ionized species in the plasma/gas mixtures play in forming the high-resolution patterns.

In a related effort, Sandia is studying and modeling the chemistry of chlorosilanes, which are used to deposit some of the thin films onto the microchip's substrate material.

An improved understanding and kinetic modeling of this complex chemistry would enhance Sandia's understanding of an integrated circuit fabrication technique that is essential to the production of custom and radiation-hardened integrated circuits and microsystems for DOE's Defense Programs. *—J.Chapman*

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